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AUTOMATIC MONITORING SYSTEM FOR TRAIN DERAILED USING IoT

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Abstract - ***Railway infrastructure plays a pivotal role in ensuring the secure and efficient transportation of passengers and goods. The fundamental element underpinning this safety is the integrity of train tracks. However, over time, the continuous operational stress on these tracks leads to the formation of potentially hazardous cracks and defects. If not addressed promptly, these issues could worsen, potentially resulting in serious accidents. This research paper introduces a novel approach to address this issue by leveraging the ESP32 microcontroller and a sophisticated light-based sensor system for real-time track crack detection.Our innovative approach integrates technology and proactive safety measures to improve the reliability and security of railway operations. Upon detecting a crack, a mobile device integrated into the locomotive initiates a controlled stoppage lasting 3 to 10 seconds. During this pause, the system automatically sends an immediate SMS alert to a preassigned mobile number. This advanced communication protocol accelerates the response time of relevant authorities, ensuring the quick and precise location of track issues. This, in turn, allows maintenance teams to efficiently address and resolve problems. The groundbreaking system significantly lowers the risk of railway accidents, contributing to the overall safety and efficiency of railway transportation. The paper details the technical aspects of the ESP32 and sensor-based solution, the implementation of the detection system, and the benefits it provides in preventing catastrophic rail incidents. By merging technology with proactive measures, this research project represents a noteworthy advancement in enhancing the reliability of rail travel and ensuring the ongoing safety of railway infrastructure.***

Keywords: *Safety measure, Train Track Crack Detection, ESP32, Light-Based Sensing, SMS Alert, Railway management*

I. INTRODUCTION

The railway sector is a vital component of contemporary transportation, enabling the smooth transit of enormous volumes of passengers and cargo on a regular basis. The importance of safety and reliability in railway networks cannot be disputed, and railway track conditions play a crucial role in this regard. Railway tracks face many difficulties; they are exposed to the vagaries of ever-changing weather, the weight of large loads, and the inexorable force of continuous vibrations. Rail operations' overall safety and reliability are severely threatened by the gradual appearance of fractures and flaws caused by the combined effects of these causes.The prompt detection and correction of track flaws is essential to preventing derailments and preventing the potentially disastrous

Nevertheless, conventional manual inspection methods, while undeniably effective, are encumbered by inherent limitations. They necessitate substantial human resources, protractedly consume time, and generate significant financial burdens, frequently culminating in operational disruptions. These methods further lack the capacity for sustained, real-time monitoring, thereby affording potential issues the opportunity to progress into more substantial complications undetected.

This introduction unequivocally underscores the fundamental importance of railway infrastructure while setting the stage for an innovative project aimed at surmounting these challenges through technologically advanced solutions. Through the integration of cutting-edge technologies, such as the ESP32 microcontroller and light-based sensing, this project aspires to provide continuous, real-time monitoring of track conditions and the immediate transmission of alerts upon the detection of track defects. In so doing, it heralds a new era in the spheres of railway safety and reliability.

In the subsequent sections of this paper, we will delve into the technical intricacies of the proposed system, elucidate its potential to revolutionize railway safety, and discuss the broader implications of adopting advanced track defect detection methods within the global railway industry. This work not only addresses immediate safety concerns but also holds the promise of substantial economic and operational benefits, positioning itself as a critical stride toward a safer and more efficient railway network.

II.EXISTING SYSTEM

In the context of railway safety, numerous established systems play pivotal roles in risk mitigation. Positive Train Control (PTC) systems, for instance, are instrumental in the monitoring and regulation of train movements, equipped with the capacity to engage brakes automatically for the prevention of collisions and derailments[2][3]. It's imperative to note, however, that these systems do not encompass fire detection capabilities.[9] Wheel Impact Load Detectors (WILD) are honed to meticulously assess impact loads on train wheels and axles, attentively addressing the potential for derailments but not extending their purview to fire detection.On the other hand, fire detection systems, systematically deployed both onboard trains and within tunnels, are impeccably tailored to the rapid identification and containment of fires.[4] It's important to underscore that fire safety stands as their paramount objective, placing a higher priority on fire-related hazards than on derailment detection.[10] Meanwhile, trackside monitoring sensors diligently inspect track conditions for conceivable derailment-inducing factors, though their focus may lack the inclusivity of comprehensive fire detection features. Furthermore, emergency response systems are thoughtfully structured to orchestrate timely responses to railway accidents, yet they generally lack the advanced capabilities associated with real-time monitoring.[5]

Expanding upon the existing spectrum, some railway networks have adopted Collision Avoidance Systems (CAS) to discern and preempt train collisions, Vibration Monitoring Systems (VMS) to identify anomalies in track vibrations, and Hot Box Detectors (HBD) for the vigilant monitoring of train bearing temperatures.[6] While these systems contribute significantly to safety within their specific domains, they do not collectively address the comprehensive imperatives of derailment and fire detection.[7]

Fig 1: Current Working System

Satellite's role in monitoring critical infrastructure - X2nSat

III.PROPOSED SYSTEM

The envisioned railway track crack detection system integrates cutting-edge technologies, utilizing the ESP32 microcontroller, light-based sensors, SIM800L GSM/GPRS module, NEO-6M GPS module, L298N motor driver, I2C module, and a 16x2 LCD display. The primary objective is to enhance railway safety by proactively identifying cracks in train tracks. The ESP32, serving as the central processing unit, orchestrates seamless communication among the various components, adhering to established industry standards.Upon the detection of a track crack, the locomotive undergoes a controlled stoppage lasting 3 to 10 seconds, facilitated by the L298N motor driver. Simultaneously, the system dispatches an immediate SMS alert via the SIM800L module to a predefined mobile number, aligning with established communication protocols.

This proactive measure expedites response times, enabling the swift identification of the track issue's location using the NEO-6M GPS module, in line with recognized geolocation standards.Moreover, the system employs the I2C module to present relevant information on a 16x2 LCD screen, ensuring real-time visibility for operators, following widely accepted display standards. Additionally, the system extends its alert mechanism to neighboring trains running parallel to the affected track, ensuring that they are promptly informed about the detected crack. Simultaneously, nearby railway officers are alerted, further enhancing the overall responsiveness to track issues.By incorporating advanced technologies and adhering to established industry standards, our proposed system represents a comprehensive solution for real-time track crack detection, advancing the safety and efficiency of railway transportation infrastructure.

IV .BLOCKDIAGRAM

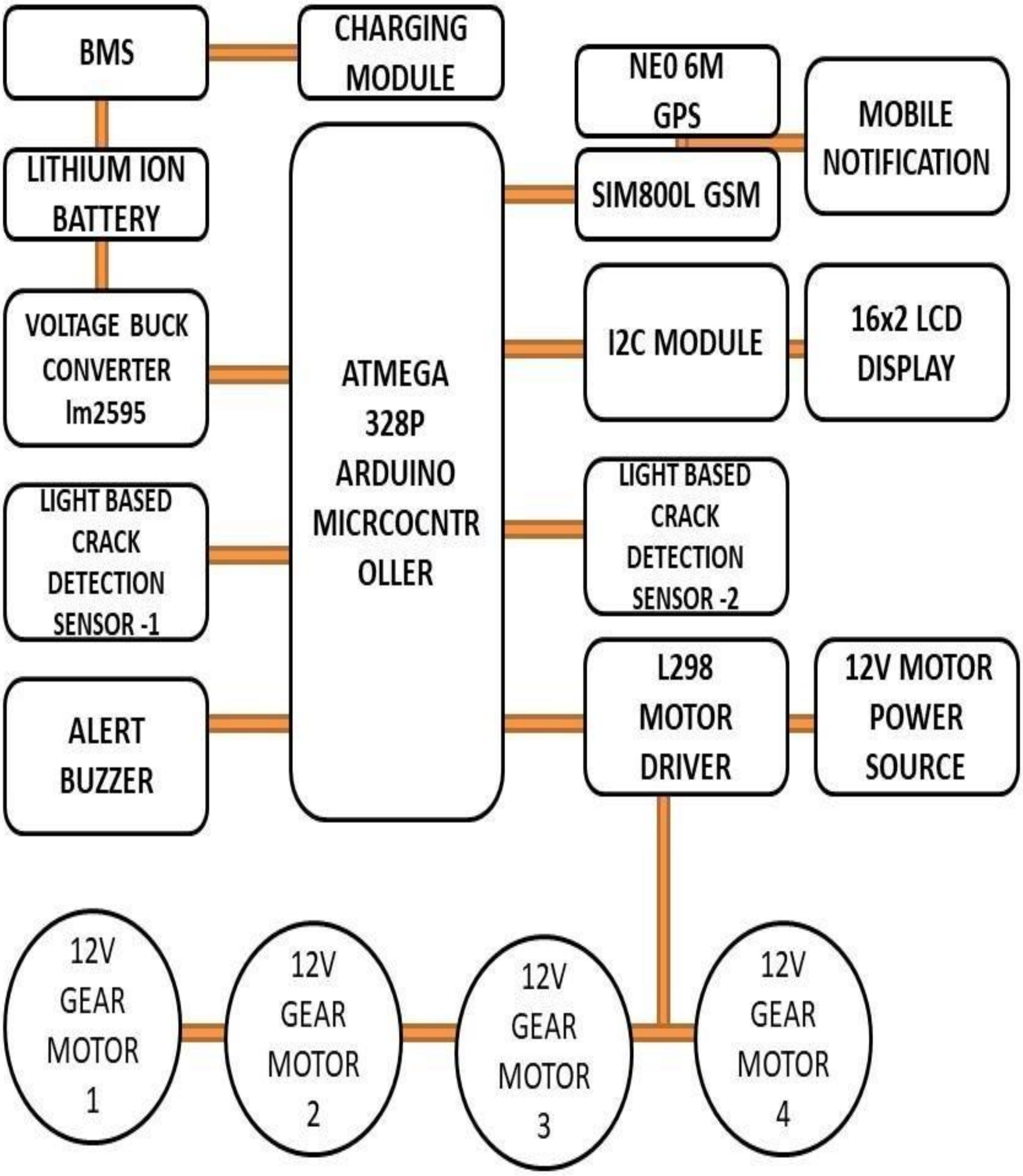

Fig 2: Block Diagram

V.HARDWARE COMPONENTS

ESP32 MICROCONTROLLER

The ESP32 can function as a slave device to a host MCU or as a fully functional standalone system, which lowers communication stack overhead on the primary application CPU.The ESP32 is an extremely flexible System On a Chip (SoC) that has a large number of peripherals that it may use as a general-purpose microcontroller.Via its SPI/SDIO or I2C/UART interfaces, Deep Sleep Operating features, 520 KB of SRAM, 448 KB of ROM, and 4MB of Flash memory, the ESP32 can interact with other systems to provide Wi-Fi and Bluetooth capability.

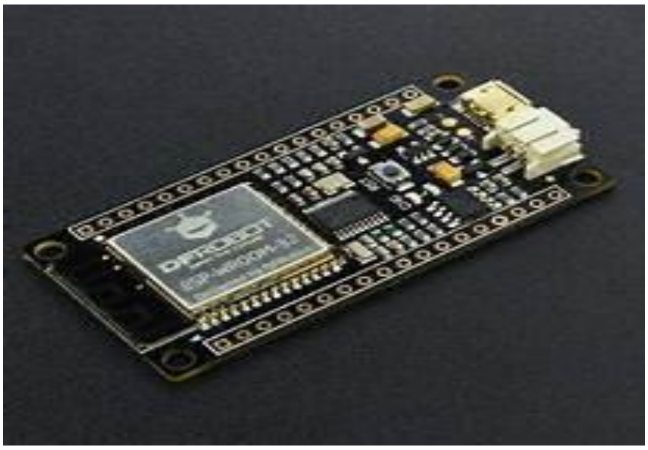

Fig 3: ESP32 MICROCONTROLLER

FireBeetle ESP32 IOT Microcontroller (Supports Wi-Fi & Bluetooth) (pimoroni.com)

SIM800L

The SIM800L GSM/GPRS module is a miniature GSM modem that can be used in a variety of IoT projects. You can use this module to do almost anything a normal cell phone can do, such as sending SMS messages, making phone calls, connecting to the Internet via GPRS, and much more.

Fig 4: SIM800L module

How to send sms and make a call using SIM800L module with an arduino (miliohm.com)

VI. FLOWCHART

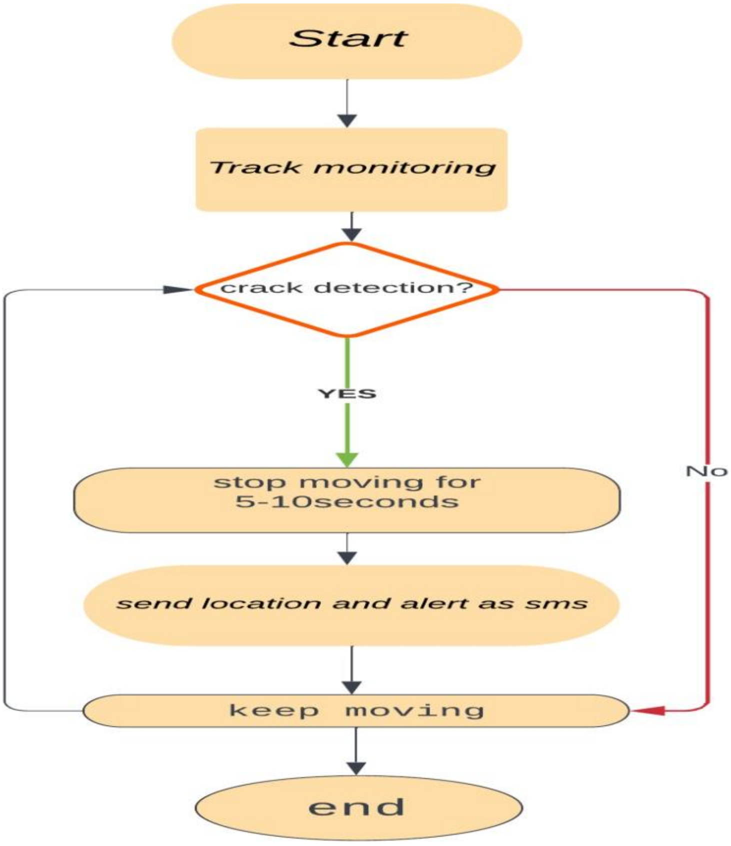

Fig 5: Workflow

PROTOCOLS:

AT: The simplest command is AT. When you run this and push enter, everything comes back OK, indicating that the serial module's communication is not working properly.

AT+CSQ: This command measures the signal intensity. In dB, the strength is checked by the first integer value. For the module to function, the signal strength needs to be higher than 5. The signal strength improves with increasing numbers.

AT+CCID: The SIM card number that is printed on the back of the card is verified by this command. Once the command has been executed, you can manually confirm the number. You may also use this to check whether the SIM card is connected to the module.

The command AT+CREG is used to verify your network registration. It is expected that the second output integer.

GPS MODULE

The NEO-6M GPS module is a powerful satellite search tool that comes with an integrated 25 x 25 x 4 mm ceramic antenna. It is a well-performing full GPS receiver. The power and signal indicators allow you to keep an eye on the module's condition. Although it's not intended for permanent data storage, an EEPROM and battery work together to assist keep clock data, most recent position data (GNSS orbit data), and module configuration. The GPS takes longer to lock initially when it is dead because it always starts cold.

Fig 6: GPS MODULE

10 Best GPS Modules For Arduino (wonderfulengineering.com)

MOTOR DRIVER

L298N motor driver IC is used in different fields like robotics, embedded, etc.   L298 motor driver is applicable where H- BRIDGE is used. This motor driver is used in high power-based applications. This IC is used where current control & PWM operable IC is required.

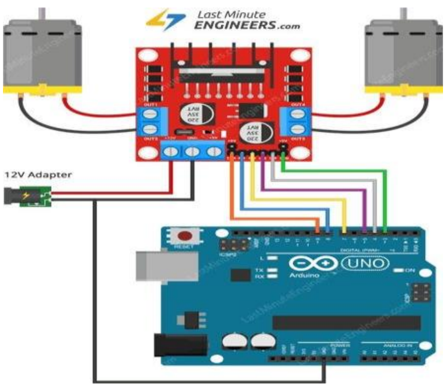

Fig 7: MOTOR DRIVEN

In-Depth: Interface L298N DC Motor Driver Module with Arduino (pinterest.com)

I2C MODULE

Inter-Integrated Circuit (I2C) communication gets its name from the fact that the I2C protocol is used to create communication between two or more ICs (Integrated Circuits). On the other hand, it should be mentioned that two integrated circuits on the same PCB may also communicate with one another using I2C. I2C LCD is a user-friendly display module that can simplify display. By using it, the process can be made easier, allowing manufacturers to concentrate on the main task at hand. We created the Arduino library for I2C_LCD, which allows users to achieve rich text and graphics display features with just a few lines of code.

Fig 8: I2C MODULE

MD0028 - IIC/I2C/TWI/SPI Serial Interface Board Module Port for 1602 LCD Display PCF8574T (tronic.lk)

16X2 LCD MODULE

LCD (Liquid Crystal Display) is a type of flat panel display which uses liquid crystals in its primary form of operation. LEDs have a large and varying set of use cases for consumers and businesses, as they can be commonly found in smartphones, televisions, computer monitors and instrument panels. A 16x2 LCD display is a very basic module and is very commonly used in various devices and circuits. A 16x2 LCD means it can display 16~ characters per line and there are 2 such lines. In this LCD each character is displayed in a 5x7 pixel matrix.

Fig 9: 16x2 LCD MODULE

LCD 16x2: Pin Configuration, Features and Its Working (elprocus.com)

VII. FUTURE SCOPE

1.**Machine Learning Integration:** By combining machine learning algorithms with historical data and real-time sensor inputs, the system may be made more predictive and capable of predicting derailments and fire hazards. Put preventative measures in place proactively.

2.**Advanced Sensor Technology:** Stay at the forefront of sensor technology advancements, exploring options that offer higher precision, reliability, and reduced maintenance requirements for anomaly detection.

3.**Predictive Maintenance:** Extend the system's functionality to include predictive maintenance. Utilize sensor data to forecast equipment wear and tear, reducing downtime and operational costs.

4.**IoT Ecosystem Expansion:**Expand the IoT ecosystem by integrating additional sensors and devices, such as cameras for visual monitoring, environmental sensors for air quality and weather conditions, and geolocation for precise incident tracking.

5.**Remote Control and Automation:**Enable remote control and automation of critical systems to respond immediately to detected anomalies. Implement automated safety measures, such as train speed reduction or emergency stops.

6.Integration with Railway Infrastructure:
Collaborate with railway authorities to seamlessly integrate the system with existing railway infrastructure and safety protocols, ensuring widespread adoption and compatibility.

7.**Comprehensive Data Analytics:** Develop robust data analytics and reporting tools to provide valuable insights into railway safety, aiding authorities in making informed decisions and optimizing operations.

8.**Energy Efficiency:** Focus on energy-efficient components and power sources to reduce the system's environmental impact and operational costs while maintaining reliability.

9.**Cross-Border and International Adoption:** Explore opportunities to implement the system in cross-border or international railway networks, contributing to enhanced safety on a larger scale.

10.**Regulatory Compliance:** Stay updated with evolving railway safety regulations and standards, ensuring compliance and alignment with industry requirements.

VIII. RESULT

The findings of this study on railway track crack detection underscore the efficacy of the innovative solution utilizing the ESP32 microcontroller and advanced light-based sensors.

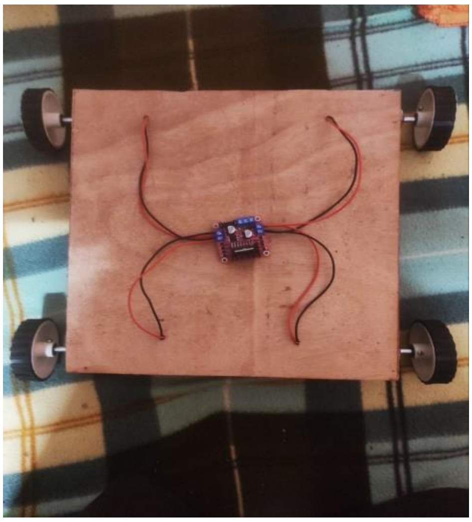

Fig 10: Working Prototype

This cutting-edge system introduces a proactive mechanism for real-time crack detection, which significantly elevates the safety and dependability of railway operations. Through the integration of the ESP32 microcontroller, the system facilitates controlled stoppages upon crack identification, coupled with immediate SMS alerts and precise GPS-based location tracking.

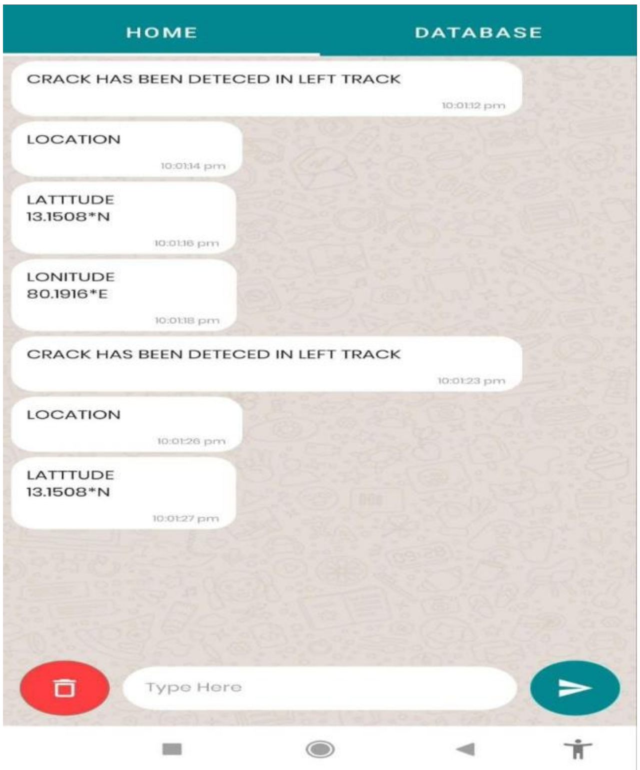

Fig 11: Application to display alert message to end user

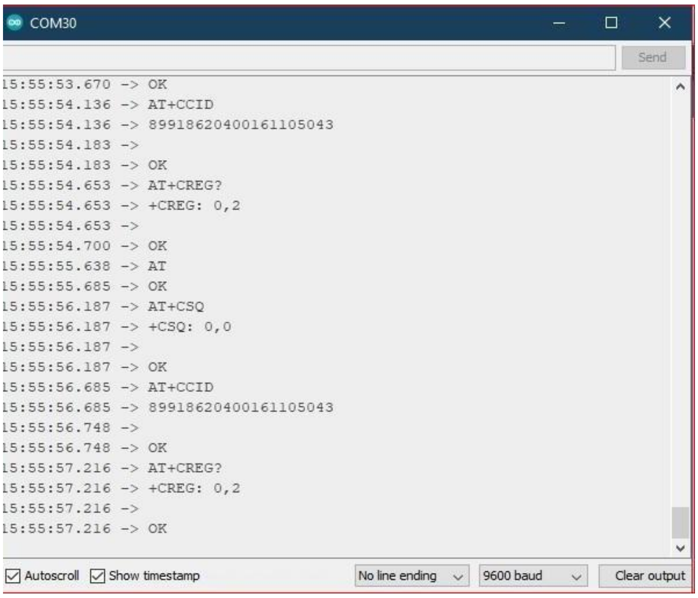

Fig 12: Module Testing

These functionalities contribute to a swift and effective response to incidents, reducing the likelihood of severe accidents and enhancing the overall safety of railway transportation. The project's success in addressing immediate safety concerns, combined with its forward-thinking considerations, positions it as a substantial advancement in ensuring the ongoing safety and efficiency of railway infrastructure

IX. CONCLUSION

The railway track crack detection represents a significant step forward in the realm of railway safety. The innovative integration of the ESP32 microcontroller and advanced light-based sensors offers a proactive solution for real-time crack detection, mitigating potential risks and enhancing the overall reliability of railway operations. The successful implementation of controlled stoppages, immediate SMS alerts, and precise GPS-based location tracking underscores the project's effectiveness in addressing critical safety concerns. As we move forward, the incorporation of future-oriented considerations, such as machine learning integration and IoT ecosystem expansion, showcases the project's commitment to continuous improvement and adaptability in the evolving landscape of railway safety. This research not only contributes to immediate safety enhancements but also positions itself as a cornerstone for ongoing advancements in railway infrastructure safety and efficiency.

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